ISRCS

Resilient Control – In next generation Automotives

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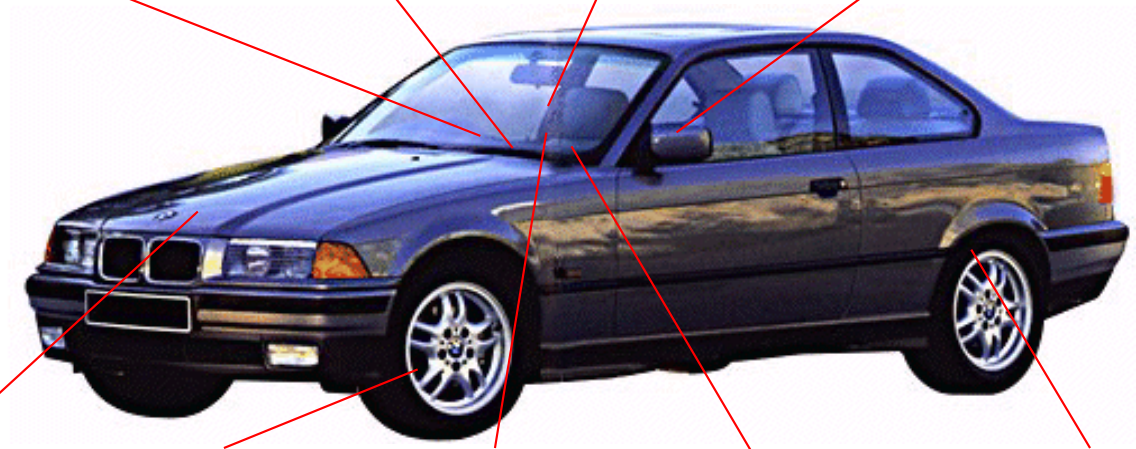
Abstract

Future Automobiles have features like: Vehicle to infrastructure / Vehicle to Vehicle wireless communication and internet communication for infotronics applications.

Resilient Control concepts in advanced distributed automotive controls, diagnostics and prognostics of failures and preventive actions in automotive environment are presented.

Real time Distributed Control with CAN network, wireless link and internet connections.



Navigation
- Global Positioning
- Digital Map
- Adaptative cruise
- Parking aid

Audio Processing
- Digital Radio
- Compact Disk
- Graphic Equalizer
- Sound Enhancement

Cellular Phone
- Voice Dialing
- Filtering

Comfort/Security Equipment
- Electrical seats
- Window lifter
- Airbag
- Anti theft

Powertrain

Anti-Lock Brakes
- Electrical brakes (BBW)

Voice Command
- Speech Recognition (E.G. lights, window)
- Speaker Verification for Secure Lock

Electronic Steering
- Electrical power Steering (EPS)
- 4-Wheel steering

- Hydraulic or Air Pressure Control
- Dynamic Control

Picture shows the use of Wireless handset to duplicate the functionalities of Car-Display.

One-can see the speed.

Using the touch panel while inside the car, turn on lights,

- **One can also get gas level detail, air tire pressure, nearby gas station information etc.**

CAR FINDER
Display shows the location of the car in a parking lot.

Wireless Communication inside vehicle

- Wireless communication techniques can also be used to perform automotive functions inside a vehicle. There are several wireless standards that can be utilized for intra-vehicle use:
- "IEEE 802.15.1 - Bluetooth",
- "IEEE 802.15.3 - UltraWideband (UWB),
- high data rate", and
- "IEEE 802.15.4 - ZigBee, low data rate".

Technology trends

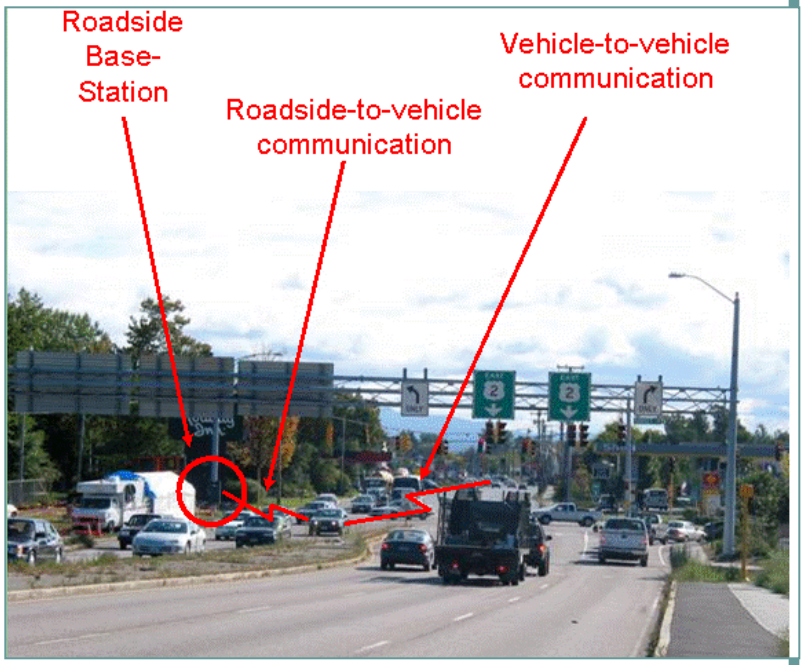
- Wi-Fi (and possibly WiMAX) enabled vehicles are expected to be on the road within the next 3-5 years. Assuming 10% market penetration, this amounts to and ~20 million vehicles in the US in near future.

- FCC has allocated 75 MHz of spectrum exclusively for V2V and V2I wireless communications (total UK 3G spectrum is ~ 70 MHz). In the UK and across the EU 30 MHZ of spectrum has been put aside for vehicular networks.

- Vehicles equipped with WiFi can communicate directly with each other (V2V), and with the fixed infrastructure (V2I). They can form Vehicular Adhoc Networks (VANET)
- New opportunities in:
  - **In-vehicle broadband wireless access**
  - **Intelligent Transport Systems (ITS) and safety**
  - **Sensor Networks on the Road**

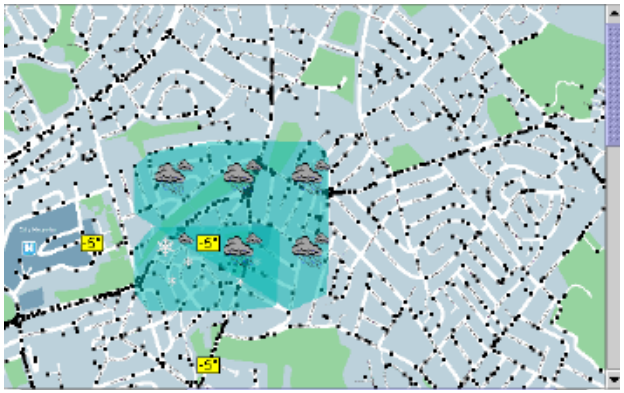
Safety and Intelligent Transport Systems

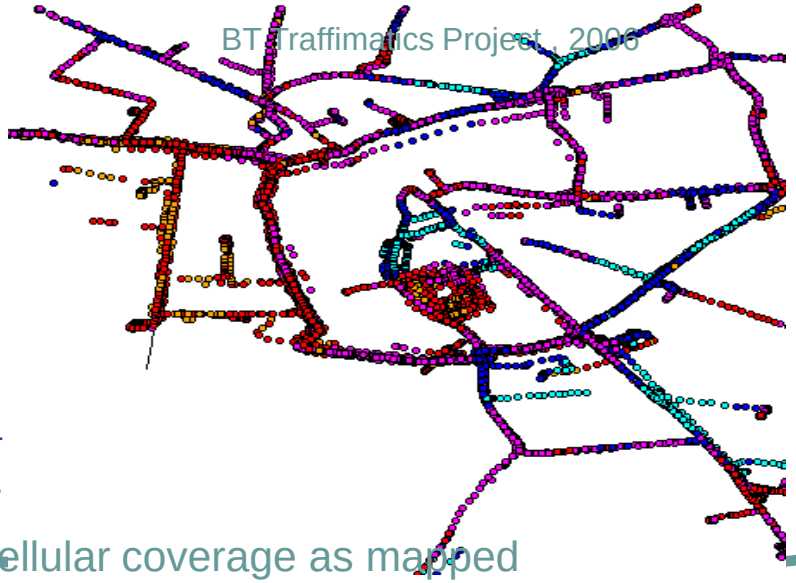
- Improve road safety, increase efficiency of road usage, reduce congestion and traffic jams
  - Early warning of road hazards
  - Driver assistance and collision avoidance
  - Real-time traffic monitoring and control on a much finer scale than is possible now (with loop detectors)
  - Real-time route guidance and journey planning
  - Cooperative driving: lane merger, high-speed platoons, self-regulating junctions
  - Real-time traffic control and re-shaping/smoothing



Sensor networks on the road

- Position sensors
  - GPS, accelerometer, compass, tilt sensor
- Environment sensors
  - CO_2, cameras, thermometer, barometer, humidity sensor
- Vehicle sensors
  - ignition, speed, engine speed, engine temperature, …
- Vehicle interior sensors
  - camera, ID card reader
- Wireless communication
  - 802.11{a,b,g}, GPRS, 3G





BT Traffimatics Project, 2006

Source: Davies, Cottingham, Jones: *A Sensor Platform for Sentient Transportation Research,* LNCS 4272. Oct. 2006.

Cellular coverage as mapped by Cambridge sentient van

UNIVERSITY OF CAMBRIDGE

Threats

Resilient design requires consideration of all threats from

- Threats due to undesirable interference through wireless link
- Threats due to malicious virus through the internet links
- Faulty sensors or parts causing failure of Power train and Engine control system
- Resilient design to handle Failure due to environment like ice, rain, oily road etc.

Threats Solution 1

At present, Wireless links and internet access are isolated from the CAN control bus to prevent virus and security of embedded controller.

Addition of Diagnostic/prognostic module which evaluates the messages in the wireless link and allow only safe communication to the CAN bus is proposed.

Solution 2 -- Prognostics/Diagnostics based on sensors on CAN bus

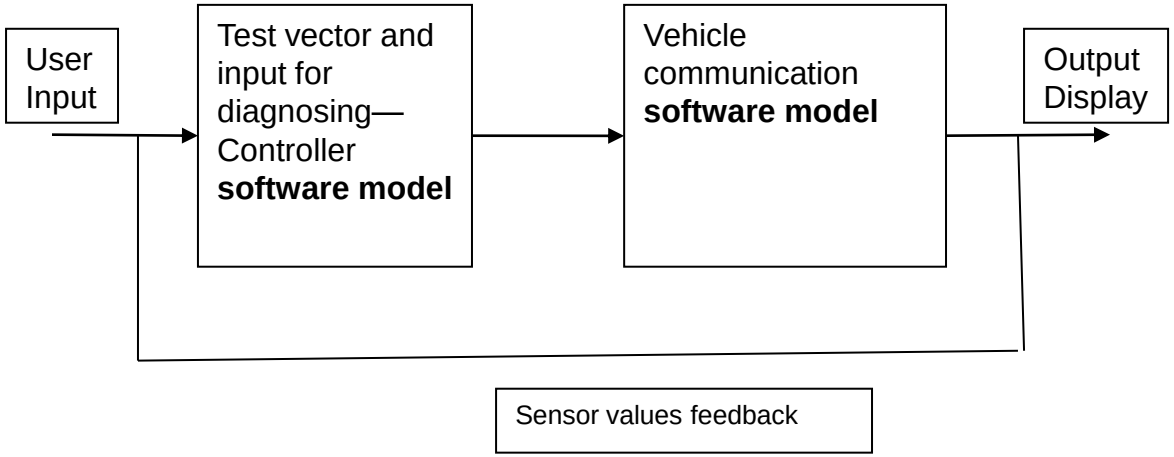
- Condition based maintenance (CBM) is the use of real time data to monitor the state of the observed system (vehicle), to determine the system's health and act only when maintenance is actually necessary. This reduces maintenance cost, system down time and maintenance time

- For example, in today's passenger cars we have sensors to analyze the oil quality and display the life of oil still left. This reduces the change of oil at regular interval of time to change of oil only when the oil quality is low.

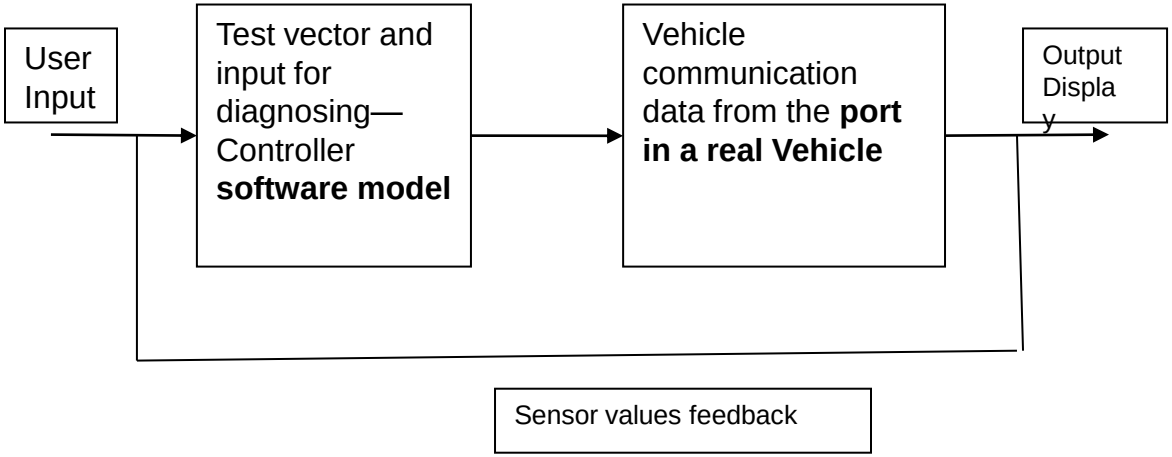
- CBM+ expands CBM concepts with the use of new technologies, processes and procedures. These are addressed during the complete life-cycle of the system (planning, design, and useful life time)

- For Legacy systems (e.g. older vehicles), appropriate CBM+ capabilities can be inserted as new technologies (sensors) emerge.
  - Sensors to monitor and record
  - Interactive and portable maintenance
  - Health and usage management system

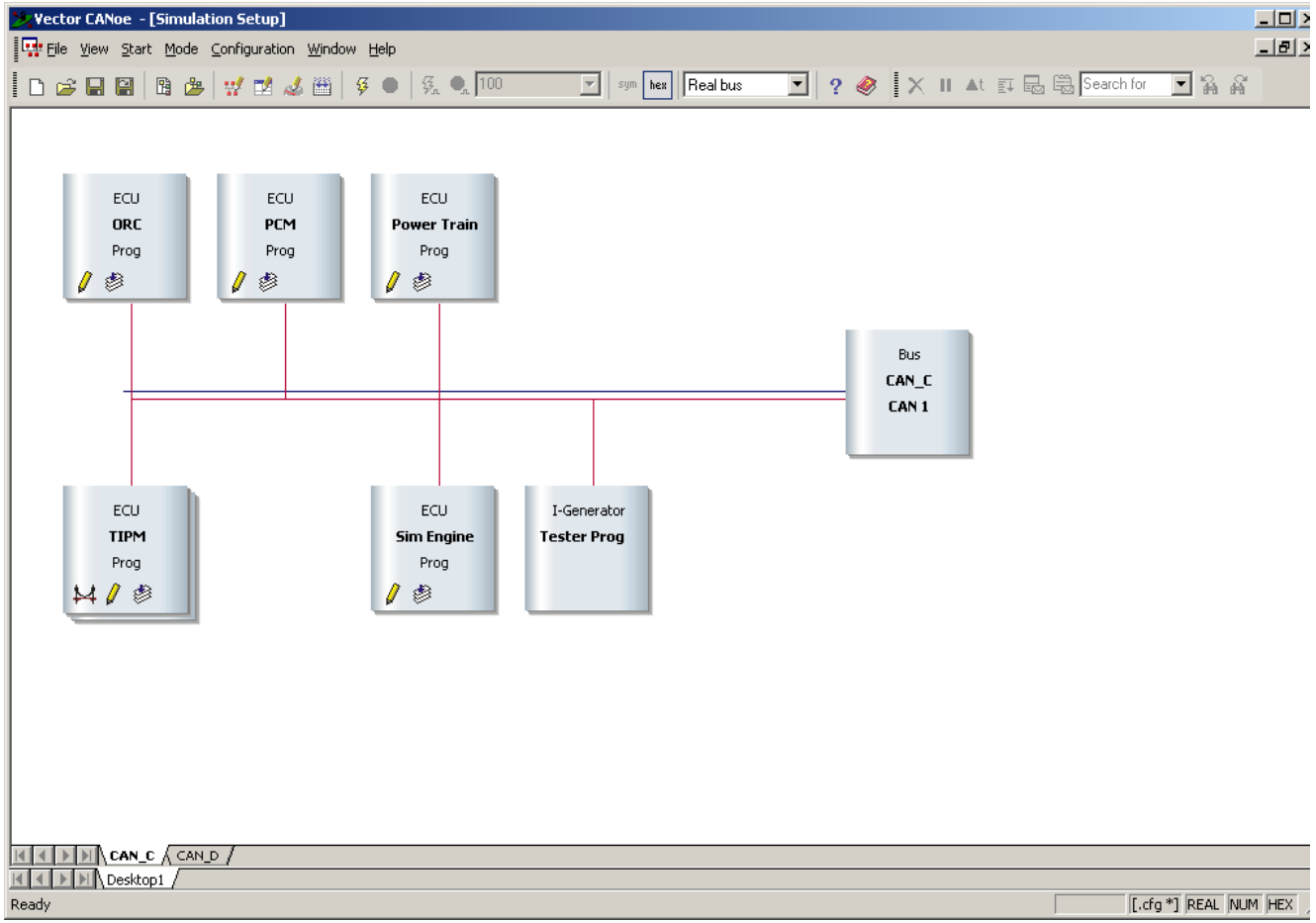
Software in the Loop Modeling



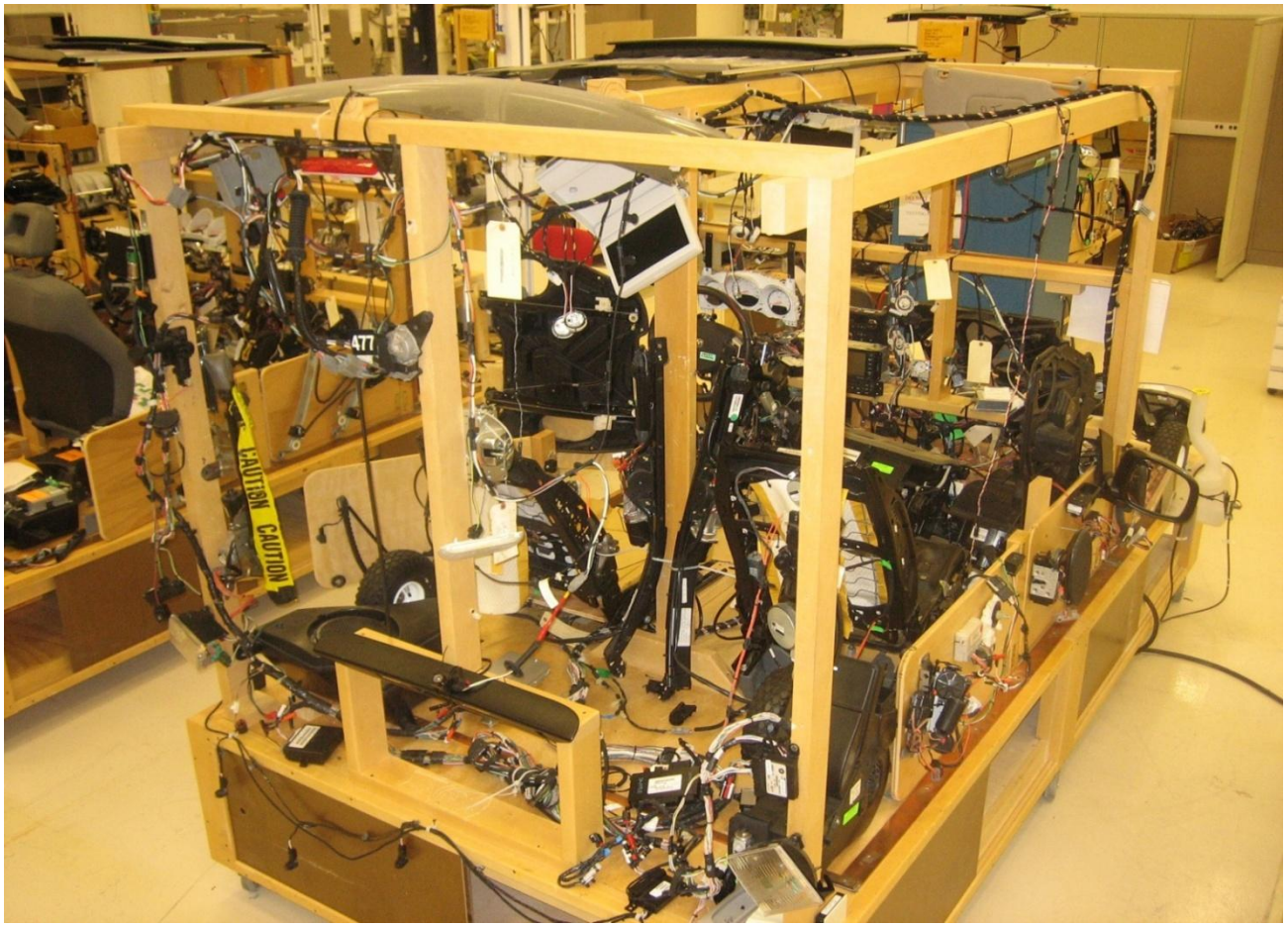
HIL



- CANoe Analyzer models various ECUs in a vehicle and can send data to test another real ECU in the vehicle. Similar to MiL/ HiL.


Vector CANoe - [Simulation Setup]
File View Start Mode Configuration Window Help
Real bus
Search for
ECU
ORC
Prog
ECU
PCM
Prog
ECU
Power Train
Prog
Bus
CAN_C
CAN 1
ECU
TIPM
Prog
ECU
Sim Engine
Prog
I-Generator
Tester Prog
CAN_C
CAN_D
Desktop1
Ready
[.cfg *]
REAL
NUM
HEX

Buck: For testing ECUs



Software in the loop

Production Code

```
// This is a sample C program to compute the factorial of n

int factorial(int v)
{
    if (v == 0)
    {
        return 1;
    }
    else
    {
        return v * factorial(v - 1); // calls itself
    }
}
```

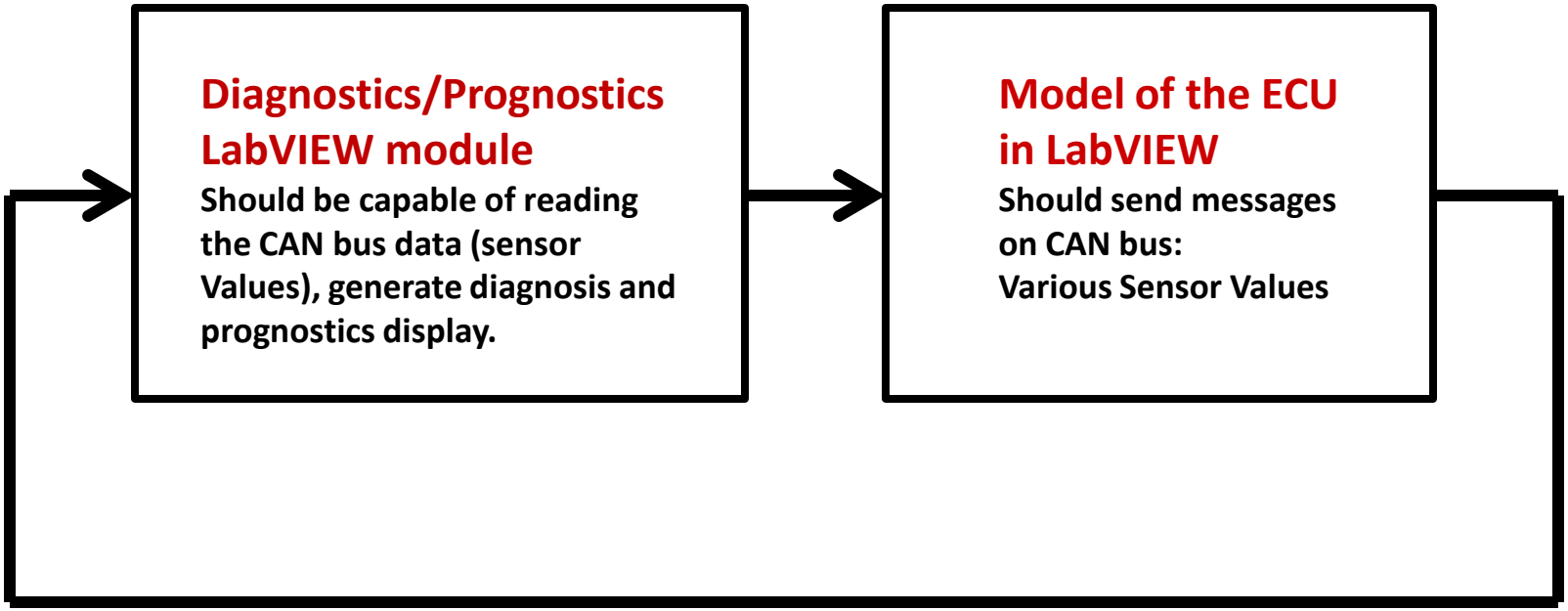
1
INPUT

Engine Model

Controller

Plant

Software in the loop for CBM-



Conclusion

- Diagnostics and prognostics of failures i.e. Condition based maintenance and preventive actions help in Resilient control of automobiles.

- **Resilient design requires consideration of all threats from wireless, internet links, faulty sensors, and other faults.**